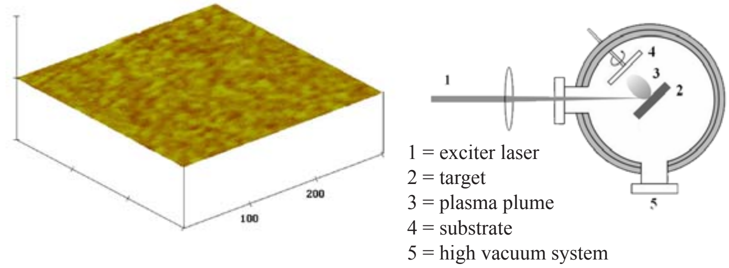
Nanocoatings for High-Efficiency Industrial Hydraulic and Tooling Systems

Superhard Nanocomposite Coatings Improve Degradation Resistance in Dynamic Applications



Atomic force microscope image of aluminum magnesium boride ($AlMgB_4$) coating as deposited. The coating has a surface roughness of 0.17 nm and a dry friction coefficient of 0.05. Schematic of pulsed laser deposition equipment.

Images courtesy of Ames Laboratory.

Industrial energy efficiency is directly linked to the wear and degradation of materials used in processing applications such as hydraulic pumps and tooling components. The preferred route to minimizing wear is to apply a protective, hard coating to contacting surfaces so that the surfaces generate less friction and resist wear. With lower friction between these contacting surfaces, less energy is required to overcome frictional forces during start-up and operation, thereby increasing energy efficiency. While the energy savings per component may be modest, substantial cumulative benefits are possible due to the large number of pumps and machining tools currently in operation within industrial manufacturing.

A new family of "superhard" (greater than 40 GPa) composites has emerged in which the hardness is derived from microstructural engineering of the constituent phases. This project demonstrated that application of the $AlMgB_{14}$-based coatings technology results in efficiency savings in both industrial hydraulics and cutting tools. The coatings combine high hardness with a low friction coefficient, and have been shown to improve the efficiency and durability of hydraulic pump components, enable high pressure operation of water-based fluids, and reduce the need for costly, wear-resistant, high alloy materials. This technology has also shown enhancements to tool life, via substantially reduced tool wear in lathe turning tests.

Benefits for Our Industry and Our Nation

Widespread use of the new superhard coatings could increase energy efficiency through diminished friction losses and increased seal reliability in hydraulic pumps. Further savings are possible through an extended lifetime of optimum cutting performance in machine tooling. Increased system reliability, coupled with decreased downtime and replacement costs, can result in economic benefits. Environmental benefits include reduced pollutant leakage through pump seals and reduced emissions due to energy efficiency.

Applications in Our Nation's Industry

Initially the advanced coatings were deployed on hydraulic system components and machining tool inserts, but other applications were developed for other high-performance, high-stress environments.

Project Description

The goal of this project was to develop degradation-resistant nano-coatings of $AlMgB_{14}$ and $AlMgB_{14}$– (titanium diboride) TiB_2 that result in improved surface hardness and reduced friction for industrial hydraulic and tooling systems.

Barriers

Major barriers included:

- Failure of existing coating solutions to combine durability with reduction in friction losses needed to improve energy efficiency in hydraulic pump components and tooling systems
- High friction, low wear resistance, and over-specification of pump size, which lead to excessive energy use in industrial hydraulic systems: Wear of the active components can decrease volumetric and mechanical efficiency by as much as 10% over the lifetime of a typical hydraulic pump
- Lack of long-term performance data to predict operating lifetime of the coatings under typical operating conditions
- Insufficient information on the correlation between vapor deposition processing method and surface properties
- Implementation of new technologies that focus on efficiency improvements in cost-sensitive markets
- Development of repeatable process parameters to ensure consistent performance of the newly-developed coatings.

Pathways

The objectives of the project were achieved through: (1) establishing the mechanical and tribological properties of single-phase and composite boride thin films; (2) developing and optimizing various vapor deposition techniques for coating application; (3) verifying the energy efficiency advantage of boride thin film over baseline performance metrics; (4) assessing lifetime energy savings in industrial hydraulic and tooling systems; and (5) scaling up deposition technology for large scale applications, complex shapes, and industrial commercialization.

Milestones

- Conduct "proof-of-concept" evaluation of the applicability of the $AlMgB_{14}$- based coatings to hydraulic and tool inset applications (Completed)
- Conduct process scale-up to generate coated prototypes (Completed)
- Validate performance and durability improvements by functional testing of production-intent prototypes (Completed)
- Estimate energy savings potential based on these results and available market information and then establish a commercialization strategy (Completed)

Commercialization

A significant portion of the last phase of the project focused on developing commercialization plans for the two applications, industrial hydraulics and cutting tools. $AlMgB_{14}$-TiB_2 (also known as BAM) targets are available for purchase through NewTech Ceramics, the current licensee of the technology. Application of the coating material onto substrate materials that contain lower percentages of alloying elements (as compared to common wear-resistant materials used in these applications) can result in a net-zero cost implementation of the technology.

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